NEW SOUTH WALES.

DEPARTMENT OF MINES.

GEOLOGICAL SURVEY.

E. C. ANDREWS, B.A., Government Geologist.

BULLETIN No. 1.

TIN

BY

E. J. KENNY.

Issued under the direction of the Hon. George Cann, M.L.A.,
Minister for Mines.

SYDNEY: WILLIAM APPLEGATE GULLICK, GOVERNMENT PRINTER.

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TIN.

According to Mr. J. E. Carne, whose exhaustive work on the tin deposits of New South Wales has been used extensively in this compilation, many references to the occurrence of tin in Australasia are to be found in early despatches and letters from officials and residents of the Colony, but these were based mainly on conjecture. It was not until 1849 that the Rev. W. B. Clarke predicted the discovery of tin in New South Wales. In a memorable letter to the *Sydney Morning Herald*, dated 16th August, 1849, he states: "And here, merely for the sake of usefulness, we suggest that, though tin has not yet been found in the Colony, it may hereafter be discovered. It is not improbable that it will be found along parts of the Murrumbidgee, where granite occurs with abundance of schorl, since, in granite districts of Cornwall, oxide of tin has a marked connection with schorl, which latter mineral is a principal ingredient in the tin lodes. The writer of this suspects, however, that he has found crystals of tin in granite from the locality mentioned, though he did not pay particular attention to the fact."

Mr. Clarke's prediction was realised two years later, when he discovered tin in granite, near Dartmoor, on the Snowy Range. The same gentleman also reported having found tin in New England. Writing on the 7th March, 1853, he mentions the occurrence of "wolfram and oxyde of tin" near Dundee and Paradise Creek.*

Active tin-mining may be said to have commenced in this State in the year 1871. C. S. McGlew was directed by a shepherd named Wills, on Newstead Station, near Elsmore, to the site where coarse detrital tin-stone had been unearthed in a saw-pit on Portion 50, Parish Anderson, County Gough. McGlew took up the ground on behalf of a small group of investors, and supervised the first washing of 6,396 lb. of clean tin-ore, in a sluice-box erected on the bank of the MacIntyre River.

Very soon after followed the discovery of tin-stone in many neighbouring localities, notable among which was Vegetable Creek,—first prospected by Thos. Carlean, in 1872.

These earlier tin finds were the more important. Among later discoveries may be mentioned Euriowie, 1884; Gundle, 1891; Ardlethan, 1912.

Ores of Tin.

The principal ores of tin are Cassiterite and Stannite. Of these the former provides by far the larger proportion of the metallic tin refined.

Cassiterite—Tin-stone; Tin-oxide.—Composition, dioxide of tin (SnO_2), oxygen 21·4 per cent, tin 78·6 per cent.; crystallization, tetragonal; clevage, imperfect; lustre, adamantine; colour, usually brown or black, rarely yellow or colourless; streak, white, greyish or brownish; hardness 6–7; specific gravity, 6·4–7·1.

Occurs *in situ* mainly in quartz veins and pipes associated with wolfram, molybdenite, bismuth, fluor-spar, topaz, tourmaline, mica, axinite and apatite in places also halloysite and amblygonite.

* Gold Discovery Papers II, pp. 344, 345.

Stannite—Tin pyrites.—Composition, sulphide of tin, copper and iron, with usually a little zinc (Cu_2S, FeS, SnS_2); crystallization, tetrahedral, usually massive, granular, and disseminated; lustre, metallic; colour, steel-grey to iron-black; opaque; streak, blackish; in many cases a bluish tarnish; some specimens yellowish from the presence of chalcopyrite; hardness, 3·5; specific gravity, 4–4·5.

Occurs associated with cassiterite, pyrites, blende, or galena, and when in sufficient quantity, is worked both for copper and for tin. Recorded from Howell and Tolwong in New South Wales, but attempts to treat it commercially have not been successful on account of the complexity of its associates, namely, lead, copper, iron, arsenic, and silver.

Conradite.—Discovered by P. J. Thibault, F.C.S. in Conrad Mines.—"A compound of stannic and ferric oxides containing tin, 68·44 per cent.; iron 9·2 per cent.; oxygen 22·34 per cent.

"To the naked eye conradite has somewhat the appearance of red oxide of mercury. Examined under a strong glass it resembles extremely fine garnets. Its specific gravity is approximately 6·2. It is non-magnetic." *

Genesis.

It is a noteworthy fact that tin deposits are confined mainly to localities where granitic rocks are developed extensively. In one or two important fields, tin deposits are associated with quartz porphyry instead of granite.

These deposits are arranged near the margin of the granites, and they may occur indifferently within the granite itself, or in the rocks intruded by the latter.

It would appear that, at various places during periods of rock-folding and mountain making, granite masses rose and entered such of the folded rocks as lay nearer the surface. These earlier intrusions are commonly of great size, and they include a considerable amount of black mica together with other dark minerals containing iron, lime, and magnesia.

After the consolidation of these massive granites, they were intruded by other, but similar types. These younger forms, however, differed in several particulars from the older ones. For example, their volume was less, and, moreover, the dark minerals were less in quantity while they contained a higher percentage of silica and water.

These were intruded in turn by veins and masses of irregular shape, composed of light-coloured granite and of a mixture of coarse felspar, quartz, and mica. The former of these, known is generally as aplite, the latter as pegmatite.

With these youngest forms the tin was associated.

Many of the minerals which are associated with tin deposits are remarkable for their content of volatile elements. For example, fluorspar, apatite, tourmaline, axinite, and topaz are common associates of tin, and each contains a percentage of an acid possessed of great solvent powers.

It may be considered that these tin associates formed, as it were, a sort of residual or mother liquor after the main granite masses had been expelled from their common source, and it may be considered that under conditions of intense heat and pressure this residual material, in part, rose and penetrated

* P. J. Thibault, "Metallurgy of Tin," 1908, pp. 27, 28.

the consolidated granite, and was deposited at positions affording relief of pressure, as at the margins of the granite. These deposits are associated commonly with great alterations of the granite, the original material being changed to a mass of mica and felspar, or of quartz, mica, and felspar, containing fluorspar and other materials in addition to the tin.

It may be mentioned also that molybdenite, wolfram, and bismuth are common associates of tin in New South Wales.

By far the most important tin deposits of this State are situated in the northernmost region of the New England Tableland. The areas worked have an intimate relationship to the well-developed exposures of granite and granite porphyry which contain dykes, segregations, pipes, and veins from which the bulk of the tin output has been derived, either as lode tin or shed material. From a study of the New England granites Mr. E. C. Andrews has shown that the more siliceous (and tin-bearing) types are intrusive into coarse granular and porphyritic granitoids, containing a percentage of iron, magnesia, and lime, distinctly higher than is the case with the former types. These tin-bearing granites form conspicuous topographic features rising high above the general level of the Tableland.*

Mode of occurrence.

1. Recent and pleistocene alluvials; and beach deposits.
2. Tertiary alluvial deposits (deep leads.)
3. True veins.
4. Pipes, impregnations, "carbonas."
5. Stockworks.

"Joint veins with shoots of ore at intervals graduate into pipe veins. A fissure vein by a change of strike becomes a joint vein and both, if they pass into a hard quartzose granite are liable to split up into a stockwork composed of numerous thread-like veins." †

(1) *Recent and pleistocene alluvials.*

The principal deposits of tin-bearing wash occur in New England, and large quantities of stream tin have been won therefrom. Box and hydraulic sluicing were the methods adopted in earlier years, but from 1900 onwards many companies have been formed to work the alluvial ground by means of pump and bucket dredges.

These deposits were first worked at Elsmore in 1872. Here the tin-stone occurs disseminated through masses of griesen, which is a crystalline, granular rock consisting of quartz and mica. The tin-bearing waste has been concentrated by the action of rain on the hillsides into a surface deposit and has been followed along stream channels into a definite "lead' under a covering basalt sheet. Wolfram and carbonate of bismuth are associated with the tin-stone, but the former does not appear to occur, in this locality, in the same lodes as the tin.

Surface deposits very similar to those at Elsmore were extensively worked at Newstead, about 4 miles further east, immediately after the discovery of those just alluded to, and as the mining population spread out in their

* E. C. Andrews.—Records Geol. Surv. N.S.W., vol. viii, pt. 2. "The Molybdenum Industry of N.S.W." Mineral Resources, No. 24, p. 25.

† T. W. E. David, "Geology of Vegetable Creek," p. 144.

efforts to prospect the neighbouring country, tin-bearing alluvial deposits were found in the creeks and gullies at Stannifer, Tingha, Stanborough, and other places in the district. These deposits being shallow were soon worked out, in fact most of them have been worked over several times by Chinese miners, who possess more patience than Europeans, and are satisfied with smaller profits.

The alluvial flats along the creeks traversing granite country in the Wilson's Downfall, Tingha-Inverell, and Deepwater Divisions are all tin-bearing, but as the deposits are of considerable depth—in places exceeding 20 feet or more—a considerable amount of stripping is required.

Cope's Creek and many of its tributaries were rich in tin ore and the gravels along their banks were a source of wealth to tin-miners.

Sandy Creek, to the south of Copes Creek, flows into the Gwydir River. Some tin ore is said to have been obtained from this creek near its mouth, but all attempts to prospect its bed for a considerable distance below its source were ineffectual, owing to the presence of strong bodies of water in the sands.

At Emmaville, where tin-mining was commenced very soon after the opening of the mines in the Inverell district, the most productive post-tertiary deposit was known as the Vegetable Creek lead.

Between the years 1872 and 1884, 15,000 tons of cassiterite are said to have been extracted from the shallow alluvial formation of this stream, within a distance of a little over 5 miles from its source. The alluvials varied from 2 to 15 chains in width, and the portions richest in stream-tin were from 1 to 5 chains in width. The average thickness of the payable wash-dirt was 2 feet 6 inches. The alluvials comprised loose deposits of sand, gravel, and rubble, with hard sheets of cement or natural tin-bearing concrete extending back for several chains from the banks of the creek. The total area of ground worked was about 150 acres, which produced 15,000 tons of stream tin, or at the average rate of 100 tons per acre, or half a hundredweight of cassiterite per cubic yard, allowing the mean depth of the wash-dirt to be 2 feet 6 inches. The depth of stripping varied from 6 inches to 9 feet.

In the Deepwater Division stream tin has been worked in numerous creeks and gullies, notably Catarrh Creek, where approximately 1,000 tons of tin oxide were obtained within a distance of one mile. The width of the deposit varied from 3 to 7 chains, and the depth of sinking to the granite bedrock was from 10 to 14 feet. The tin-stone was mostly black, but occasionally ruby-tin and resin-tin were also obtained. The grains were very much waterworn, and their average diameter was about $\frac{1}{20}$ inch.

Near Wilson's Downfall, Herding Yard and Ruby Creeks were the chief centres of alluvial mining. The tin ore was derived from the disintegration of dykes, lodes and impregnations in granite country extending from Bookookoorara River to Maryland Creek. The alluvium was worked for several miles from the head of the creeks downwards, sinking being through clay, sand, granite drift and wash-dirt, the latter sometimes cemented.

Tin-bearing shallow alluvial deposits have been worked to a considerable extent in other localities. Mention may be made of Basin Creek, near Germanton; Boro, near Tarago; Tumbarumba, Mount Tallabong, and Burra

Burra Leads, near Condobolin; Grenfell, Mount Werong; Tantawanglo Mountain, near Cathcart; and Tanja Creek, near Bega. At Mount Brown, near Tibooburra, tin occurs associated with gold in the "granite diggings."

Near Ardlethan a detrital deposit of decomposing granite and quartz-porphry with fragments of sedimentary rocks is being worked with profitable result. The floor is uneven, and the depth of sinking varies from 25 to 86 feet. The average content is approximately 1 per cent. of tin in the New Venture lease, and 3 cwt. of tin oxide per load lower down.*

Beach Deposits.

Tin oxide in an extremely fine state of division occurs sparingly on the beaches and in beach sand accumulations between Byron Bay and Clarence Heads, and in less quantity between Port Macquarie and Cape Hawke, near Seal Rocks, at Shellharbour, and Termeil. The following minerals are also present:—Zircon, garnet, ilmenite, monazite, gold, and platinum.

Attempts to treat the sands have been unsuccessful. The practice while gold was being won, was to ship the small amounts of concentrates abroad, where they were treated for platinum and tin, and, possibly, monazite.*

(2) *Tertiary Alluvial Deposits (Deep Leads).*

The tin-bearing greisen, the disintegration of which produced the rich surface deposits of tinstone, already alluded to, at Elsmore and Newstead, was also undergoing decomposition during early tertiary times, and as a consequence of this action large quantities of stream-tin were deposited in the valleys which received the drainage of this country during the tertiary period. The deposits were covered with a considerable thickness of alluvium, consisting of gravel, sand, and clay, and containing leaves, nuts, branches of trees, and large logs, all of which are now preserved in a fossilised state. Eventually the valleys were invaded by streams of molten lava, so that they have since been protected from denudation by a considerable thickness of basalt. The country intersected by these deep leads consists of hard bluish-grey claystones, of permo-carboniferous age, and areas of granite and greisen. There are also numerous dykes of eurite, diorite, and basalt. Frequently on the higher ground are found deposits of older volcanic ash, which now consist in part of the mineral bauxite.

The Elsmore Valley Lead.—About 10 miles south-east of Inverell, was, in the first instance, prospected by a bore. At a depth of 187 feet a bed of wash-dirt, 10 feet 6 inches in thickness, and estimated to yield 15 lb. of stream-tin per load, was intersected. At a depth of 201 feet 6 inches another bed of wash-dirt, 18 inches thick, and containing at the rate of 100 lb. of stream tin per load was met with, and 2 feet below this was a third deposit of wash-dirt 1 foot thick. This lead was worked by the Elsmore Valley Tin-mining Company, whose main shaft reached a depth of 225 feet. The deposits of stanniferous wash were found to vary considerably in thickness, and in some places the two lower beds united, while in other places, they were separated by several feet of sand and clay. The yield of tin was variable, but it is stated that the average contents were about 100 lb. of tinstone per load, and the mean thickness of wash-dirt was about

* L. F. Harper, Min. Res. No. 29, "The Geology and Mining Developments of the Ardlethan Tin Field," pages 18-20.

* J. E. Carne, Min. Res. No. 14, "The Tin-mining Industry [illegible] in New South Wales, pages 280-295.

2 feet 6 inches. The tinstone is said to have been of good quality assaying from 76 to 77 per cent. of metallic tin when cleaned and containing only a trace of wolfram.

The Newstead Lead.—This lead was traced from surface deposits of tin ore on the slope of a greisen range, and was found to deepen gradually as it was worked northwards, until at the spot where it passes under Newstead Creek, Cody's shaft has a depth of 70 feet. Some hundreds of tons of tin ore were extracted from this claim. The Newstead Company sank two shafts north of Cody's claim, the first of which had a depth of 130 feet, and from which very rich deposits were worked. Eighteen tons of clean ore were obtained from one drive, but no blocking-out was done. One load is said to have yielded 360 lb. of ore, but the bottom was found to dip so rapidly that a second shaft was sunk to a depth of 190 feet, in solid granite, on the bank of the creek, and a drive was put in under the creek. About this time mining operations were stopped on account of want of capital. This lead is said to have an average width of 140 feet. There is every reason to believe that there are payable deposits of ore here which only require capital for their development. Other tertiary tin-bearing leads occur in the Inverell district, such as The Donegal, Dick Jones' Lead, Brickwood's Lead, McMillan's Lead, Standard Lead, Jealousy Lead, Walmesley's Lead, and The United Lead.

Near the junction of Cope's Creek with the Gwydir River are several isolated basalt-capped hills marking the course of an old river-bed, approximately parallel with the Gwydir. Under the basalt is a considerable deposit, 14 feet thick in places, of water-worn quartz pebbles, with large boulders of decomposed granite. This alluvial drift rests on a granite bottom, and is at the present time being worked for diamonds, which occur in considerable quantities but of small size. The diamonds are accompanied by topaz, sapphire, zircon, tourmaline, ilmenite, magnetite, spinel, and pleonaste, and the wash-dirt contains, in addition, as much as 15 lb. of stream tin per load. Although the tin is not, therefore, in sufficient quantity to render its extraction profitable, it forms a by-product, the value of which contributes towards covering the cost of extracting the diamonds. The gems enumerated are found associated also with the stream tin in Cope's Creek, and many of the other watercourses in which deposits have been worked in the Inverell District.

In the Emmaville or Vegetable Creek District the Tertiary alluvial deposits have been divided into two classes, viz.:—(*a*) those which are capped by lava; and (*b*) bare deposits, or those from which the cap of lava has been removed by denudation. Examples of the second type occur at Scrubby Gully, Surface Hill, Ruby Hill, and at the Y Water-holes. The deposits at the Y Water-holes are, by far, the most important of this class. They have an area of 1,100 acres, and the depth of the wash averages about 20 feet. The alluvial deposits of clay and sand show characteristic current bedding. The ore is richest at the base of the beds, while the surface deposits contain more stream tin than the intermediate beds, owing to their having received the ore from the sluicing of a considerable thickness of sands which at one time overlay them, but which have since been removed by denudation. There is no evidence of the concentration of ore in old channels in this deposit, and it is therefore, probably of lacustrine origin. Portion of the Graveyard Lead is of a similar nature and has been worked by the Y Water (Emmaville) Tin Mining Company operating a pontoon sluicing plant at Cadell's Freehold.

The following are the principal basalt-capped Tertiary leads which have been worked for tin in the Emmaville district :—

1. The Vegetable Creek Lead, including the basaltic country to Kangaroo Flat, Hall's Sugarloaf, Paddy's Sugarloaf, and the Surprise.
2. The Graveyard Lead.
3. The Springs Lead.
4. Rocky Creek Lead.
5. Wellington Vale Lead.

Of these, the Vegetable Creek Lead has proved by far the most important, and there can be no doubt that during some portion of Tertiary time it formed the main drainage channel of this country. In portions of its course there were two distinct flows of lava, an older and a newer, each covering a bed of tin-bearing wash. Up to the year 1886 the produce of these latter was 6,000 tons of stream tin in a distance 2 miles 30 chains. At one place an area of 5½ acres of gravel, having an average thickness of 3 feet, yielded 2,000 tons of tin-ore. The main direction of the lead was westerly, and its width varied from a few feet up to, in one instance, as much as 400 feet. The thickness of the wash in places approximated to 14 feet; but its average was about 3 feet. Blanks occurred in the lead where the fall of the old river-bed was relatively steep, the tin-ore having been washed down to places where the bottom was relatively level.

The Vegetable Creek Lead had two main feeders or tributaries, namely, the old Rose Valley Lead and Fox's Deep Lead.

The Graveyard Lead is south of, and approximately parallel with the Vegetable Creek Lead, and the two leads probably junction about 6 miles west of Emmaville. A considerable amount of basalt-covered country extends from this point in a northerly direction through Kangaroo Flat to Avoca and the Fishing Grounds, and, as drift has been worked at these places, at a level sufficiently low to allow for the average fall of the old river valley, it is probable that the main lead will be proved ultimately for a distance of at least 15 miles, though it is scarcely probable that the tin-bearing wash will be found to be continuous ; on the contrary, it is much more likely that stretches of unproductive wash will be found, where the old river has intersected country which is not tin-bearing.

The Wellington Vale Lead.—The head of this old alluvial deposit is situated at a locality known as the Nine-mile, to the north-west of Deepwater. Rich shallow deposits of stream tin have been worked here along a flat trending from the south-eastern slope of Battery Mountain ; but after being followed to the east and north-east for about a mile, they were found to dip below the basalt, a narrow strip of which extends for many miles southwards, forming a covering to the Wellington Vale Lead. A deep trial shaft in portion 95, parish Wellington Vale, county Gough, proved three distinct basalt flows separated by drift, but unfortunately only the slightest traces of tin were obtainable from the abundant channel drift during driving operations in it for over 365 feet.

As the head of the lead was not remarkably rich, and the downstream country non-stanniferous, the prospect was never encouraging at the site chosen, for only the finest tin grains would have drifted so far from their source in Battery Mountain Even at the stream-heads, where the heaviest deposits would have concentrated, the yields were never comparable with those of leads like Vegetable Creek." *

* J. E. Carne, Min. Res., No 14, "The Tin Mining Industry of New South Wales," p. 153.

The geology of Emmaville is, in most respects, very similar to that of the country round Inverell. The oldest sedimentary rocks are the bluish-grey claystones of the carboniferous period, and these have been intruded by tin-bearing granite and by quartz-felsites and diorites. There was a great amount of volcanic activity during Tertiary times, as is attested by the sheets of lava and deposits of volcanic ashes. These latter occupy an area of nearly 12 square miles, and they vary in thickness from a few feet up to 40 feet. The beds consist at the surface of a red, dusty soil, and pass downwards into red, yellow, or grey tuffs, and compact pisolitic rock containing a variable percentage of alumina and peroxide of iron; these in their turn graduate into rotten, spongy basalt. These ash deposits consist essentially of the mineral bauxite, and will doubtless be of considerable value in the future for the manufacture of aluminium.

At Bailey's Mine, Rose Valley, there is an extremely interesting occurrence of a lead overlaid by a felspar porphyry lava. This occurrence was first recorded by S. H. Cox, A.R.S.M., and is the only known instance in Australia of a lead covered by an acid lava (Journ. R. Soc., N.S.W., vol. XX, 1886, p. 105).

Bailey's Mine is situated on the junction of intrusive felspar porphyry with the carboniferous claystones, and the floor of the lead is formed sometimes of the one rock, sometimes of the other. It is probable that the acidic lava covering the wash was contemporaneous with the basalts which are found overlying the other deep leads in the district, and represented the earlier products of the volcanic eruptions.

Tin-bearing Lodes.

Stanniferous lodes comprise (*a*) Fissure Veins, (*b*) Joint Veins, or those following joints in its granite or felspar porphyry, and (*c*) Pipe Veins. The veins are found most frequently in the granite, and they occur almost exclusively with a distance of about a mile and a half of the junction between the granite and the claystones. Professor David states that in the Emmaville district—

76 veins are enclosed in granite.
8 ,, ,, quartz-porphyry.
3 ,, ,, porphyroid.
3 ,, ,, claystone.

He noted also that of seventy-seven veins in this district in which tinstone occurs nineteen consist of quartz and tinstone only, and eight of felspar and tinstone only; also, that sixty-nine veins contained quartz, twenty-nine contained chorite, and twenty contained felspar. The following minerals also occur in different veins in the district, viz.:—Mica, mispickel, iron pyrites, fluospar, tonomaline, wolfram, zincblende, galena, copper pyrites, bismuth, molybdenite, vesuvianite, stilbite, hæmatite, phyrrhotine, manganese, scheelite, and beryl.

Strike of Lodes.—The average strike of fifty-four veins was observed to be N. 39° 15″ E., the range of strike being N. 24° E. to E. 20° N.

Dip.—The average dip of thirty-seven veins observed was 77°

33 veins dip north-westerly.
10 ,, ,, south-westerly.
3 ,, are vertical.

The ore in most of the tin-bearing veins occurs in chutes, which are inclined more or less steeply from the horizontal, and obliquely along the plane of the lode. The average length of the six largest chutes observed was 100 feet; average width, 1½ feet; average depth 6 feet; average dip 26°; average horizontal distance between chutes about 80 yards; vertical distance between chutes, 50–90 feet. Eleven chutes were observed to dip north-westerly; two chutes were observed to dip south-westerly.*

3. *Fissure Veins.*

Butler's Lode, 10 miles from Torrington, extends for a mile, approximately, through eurite and granite-porphyry, striking E. 30° N. The tin ore is disseminated regularly through the lode, which is in the nature of a true fissure, with well-defined walls. The lode splits in places, and is richest on walls, but in many places payable ore extends throughout the whole width of from 10 to 30 feet.

Large veins, lined with very large quartz crystals, exhibiting secondary growth, occur. Chlorite is a very prominent constituent of the lode material, and invests quartz crystals and isolated kernels of cassiterite, the progressive order of deposition being quartz, tin-stone (and wolfram), and chlorite, in the order named.

A considerable amount of mining and developmet has been done with satisfactory results, and the lode is being worked at present by Butler's Tin Mines, N. L., who have erected a costly and up-to-date plant.

Dutchman's Lodes (near Torrington).—Two main lodes, 3 to 4 feet wide, having well-defined, slickensided walls, contain tin-stone in a gangue of quartz and chlorite. In the lodes are developed remarkable cavities, lined with quartz crystals. at the base of which cassiterite occurs. These deposits have been considerably developed, and are now being worked by the Harts' Tin-mining Co., but, as in the case of the preceding mine, operations are frequently hampered by lack of water supplies.

In the vicinity of Emmaville several well defined lodes have been worked, the most productive being Gulf Stream, Hall's Grampians, McDonald's, and Ottery Lodes. The former has an average width of 2 feet, but appears to have a maximum of 8 feet. The gangue consists of quartz and chlorite, with decomposed white felspar, while fluorspar and wolfram are associated in small quantities with the tin-stone. Here a remarkable patch of beryl in a matrix of jasperoid quartz and mica was exposed in the workings.

Halls' Grampians are a series of very thin veins of quartz and tin-stone traversing highly altered claystones. The vein material contains mispickel, iron pyrites, black oxide of copper, zinc-blende, fluorspar, galena, and white mica.

MacDonald's Lodes are situated in a dyke of hornblende felsite about 12 feet wide, striking east 20 degrees north through a hornblende granite near its junction with slate. The dyke is traversed by numerous veins, from mere threads up to 3 inches in width of black tourmaline, the larger of them containing quartz in the central zone. The tin occurs as impregnations both in the quartz and in the tourmaline veins.

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*T. W. E. David: "The Geology of the Vegetable Creek Tin-mining Field."

The Ottery Lodes are situated about 2 miles to the north of the village of Tent Hill. There are at least five distinct lodes, and they intersect dykes of hornblendic granite and eurite, within a distance of a few chains from the junction line of these intrusive dykes with the permo-carboniferous claystones. The outcrops of all the Ottery lodes consist of quartz containing tinstone, and they may be traced on the surface for a considerable distance in a south-westerly direction towards the head of the old Vegetable Creek Lead, and there can be very little doubt, therefore, that the extremely rich deposits of stream tin which were recovered from these shallow deposits were derived from the Ottery lodes and from stockworks occurring throughout the associated areas of claystone. The main lode was worked for a distance of 1,000 feet along the strike and a depth of 350 feet, measured on the underlie, which varies from 30 degrees to 80 degrees towards the north and north-west. In the upper levels the lode was characterised by clean and well-marked walls showing slickensides, but in the lower portions of the mine there were seldom any signs of defined walls ; the country outside the hanging and foot-wall lodes was as much mineralised as the "horse" which separates them. Specks of copper pyrites and small crystals of galena and zincblende have been seen in the lodes, but these minerals occur in small quantities only.

Black Swamp (Parish Annandale, County Clive).—Here there are two principal veins of quartz, replaced by tinstone in places and traversed by a central crack, on either side of which the quartz passes into a quartzose granite with eurite dykes.

Cemetery Lodes are examples of richer tin content, where felspar predominates in the veinstuff.

McDowell's Contact Lode, 20 miles north of Emmaville, occurs at the junction of granite and slate, and strikes approximately N. 75° E. The quartz vein averages 10 feet in width, and is often highly micaceous, containing, in addition to the tinstone, bismuth, zincblende, galena, pyromorphite, and chalcopyrite.

The Planet Lode, near the village of Stannum, was the first tin lode prospected in the State, leases being pegged in 1872. The country rock is porphyry and the lode contains a little wolfram, while arsenopyrite is prominent at depth.

In the Cope's Creek district several tin lodes occur associated with numerous veins and dykes trending in a direction E. 5° N. and north-east through the granite mass. The largest are developed where the quartz veins traverse felspathic eurite dykes. At Elsmore Hill tinstone occurs in quartz veins and greisen masses associated with the micaceous granite. Similar occurrences are developed in an extensive granitic mass between Bookookoorara River and Maryland Creek.

In the Barrier Ranges district tinstone occurs in dykes and veins of pegmatite, notably at Euriowie, Waukeroo, and Kantappa.

Euriowie Deposits.—Here the cassiterite is contained in a series of sub-parallel to parallel pegmatite sills, arranged along definite schist zones of pre-Cambrian age, trending slightly west of north, and disappearing beneath the Poolamacca series at their unconformable junction with the Willyama, or older group. The pegmatites vary considerably in texture, and in many places they exhibit the characteristics of greisen. The lenticular form of the sills, with bulging walls and associated pinching, indicates formation

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under pressure. The strained schist walls have been replaced by siliceous material, resulting in the development of topaz-rock, halloysite, and amblygonite. A considerable development of tourmaline is noteworthy, and the tinstone occurs not in disseminated form, but rather in irregular patches, with a little scattered ore between them. The largest output was derived from the ore-bodies in the Huel Byjerkerno, while less returns have been obtained from the Mount Euriowie and Lady Don mines. It is estimated that over 100 tons of dressed ore were despatched from this field. The occurrences at Waukeroo and Kantappa have a similar nature and origin.

At Toonallook, near Albury, the lode material consists of greisen and coarse pegmatite with occasional aplitic veins intruding slates. At the contact the slate is altered into mica-schist with greisen and chiastolites.

Jingellic Tin Lodes.—On the southern border of New South Wales a series of parallel tin lodes occur at Jingellic, about 60 miles to the east of Albury. Here again the mineral is found under the same geological conditions which mark its occurrence in the northern fields—that is to say, the deposits occur in granite close to its junction with slate. The lode material is bluish quartz, in which the tin occurs in very thin seams usually on the walls. Wolfram is an associate; the proportion of tin to wolfram has been estimated as 3 to 1.

Gundle Deposits.—Ten miles from Rolland's Plains, Wilson River. The tinstone is disposed on horizontal "floors" of aplite.

Mr. J. E. Carne writes of this deposit as follows:—"From the mode of occurrence of the ore-bearing aplite, as flat bands or 'floors' in the non-stanniferous granite and the close association of the tin-ore, I am of opinion it is an intrusive 'ore-bringer' in the latter, and therefore younger. The Gundle aplites are identical with those of New England."*

Mt. Tallebong Lodes.—45 miles north-west of Condobolin. Here the lodes occur within a narrow belt of slates and sandstones at a distance of approximately 1 mile from a granite mass. Their general strike is north 25° west, and the width varies from 1 to 10 feet. The Mount Tallebong Tin Mining Syndicate has put down a shaft to a depth of 130 feet, where the lode maintains its value.

Ardlethan Deposits.—These important deposits comprise a series of pipes, impregnated zones, joint and fissure veins occurring in granite and porphyry close to their contact with sediments, probably of Devonian age. The tin-bearing matrices bear a distinct relationship to the prophyry intrusion and its alteration and replacement zone. The alteration has resulted in a marked development of tourmaline, topaz-rock, and sericite.

Associated minerals are:—Arsenopyrite, pyrite, wolfram, chalcopyrite, bismuth ochre and bismuthinite, cerussite, molybdenite, and pyromorphite.

This field is now being, and has been since 1912, extensively developed with results which are highly satisfactory. Three groups of mines are in operation, viz., at Bygoo, Carpathia Hill, and Bald Hill.

The Carpathia group is the most important of these, and large companies, as for instance the Carpathia White Crystal and New Venture produce a big yearly tonnage, the ore being treated in the local batteries and concentrated.

* J. E. Carne, Mineral Resources, No. 14, "The Tin-mining Industry of New South Wales, p. 288.

The ore won is classified as follows :—

·7 to 3 per cent. tin	"Seconds."
3 to 14 per cent. tin...	"Millings."
15 to 30 per cent. tin	"Special millings."

Anything over this, and some of the ore goes as high as 63 per cent. tin, is termed *"selected."

The total value of the output from the field to the end of 1921 is £436,128.

The Conrad Lodes occur in a tongue of acid granite at no great distance from its intrusive junction with the Tingha granite. The metallurgy of the ore bodies is extremely complex by reason of the association of "Conradite" with arsenical pyrites, iron pyrites, zinc-blende, and copper pyrites. The lodes are persistent and were opened up in 1890 for silver and lead, but at lower levels copper and tin in addition were found.

Two types of concentrate were produced (1) silver-lead and (2) copper-tin, the latter of which was smelted at the mine and the matte shipped to Europe.

The Tolwong Lode is situated about 9 miles S.SE. of Marulan, and outcrops on the side of precipitous gorge excavated by the Shoalhaven River in quartzites and slates of Ordovician age and Marine sandstones. The lode is well defined, varying from a few inches to over 8 feet in width. The dip apparently is S. 65° W. at 30°.

The principal lode material appears to be mispickel but in addition to the tin sulphide, chalcopyrite, galena, and zinc-blende are associated as a highly complex sulphide ore, which has so far defied the efforts of the metallurgist to determine a satisfactory process of extraction.

An average sample selected from the various tunnels yielded :—

No. 08-2593—Copper	6·12	per cent.
Tin	2·30	,,
Arsenic	15·80	,,
Gold	a trace.	
Silver	2 oz. 9 dwt.	per ton.

The presence of tin ore in sedimentary rocks at Tolwong at some distance from granite is of interest. It is probable that felsitic contemporaneous rocks may be included in the former, which have not been carefully examined.*

Joint Veins,—Examples of this type of vein are :—

(*a*) *Stannum lode*, on west bank of east branch of Bark Hut Creek, occupies a joint plane in hard aplitic granite, striking N. 30° E., and dipping at 78° in a westerly direction. In places the tinstone occurs as a mere streak, and in certain places is not even visible. Carbonate of iron is a common mineral of the gangue.

(*b*) *Cliff lode*, one and a-half miles north-west of Stanuum, on Battery Mountain, is a network of joint veins in aplite. The veins vary in width from mere threads to 3 inches. An average yield approximating to 6 cwt. per ton was obtained.

(*c*) *Brennan's lode*, at the head of Two-mile Creek is remarkable for the absence of quartz gangue, and the occurrence of tinstone with felspar in a joint of the granite country. Cassiterite is also present in disseminated form in the wall rock.

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*Mineral Resources. No. 29, by L. F. Harper, "The Geology and Mining Development of the Ardlethan Tin Field."

* J. E. Carne, Mineral Resources, No. 6, 1908, pp 413, 414.

4. *Tin-bearing Pipes.*

Pipes are a peculiar feature of both the Emmaville and Tingha–Inverell districts. They occur in granite as a rule, and are in the form of irregular pipes, somewhat suggestive in certain cases of twisted cylinders, dying away in places to mere threads. Individual pipes may present all variations in dip, from zero to vertical. In very few instances do they extend to any considerable depth, but disappear gradually at depths of 30 or 40 feet. Large pipes may be as much as 4 or 5 feet in diameter, and within these limits the tinstone occurs disseminated through a gangue of felspar, quartz, and chlorite.

A typical example of this class of deposit is known as Cox's Pipe, on the east side of Sutherland's Water, one and a-half miles from Tingha.

The following figures and description are by E. C. Andrews, B.A., Geological Surveyor :—*

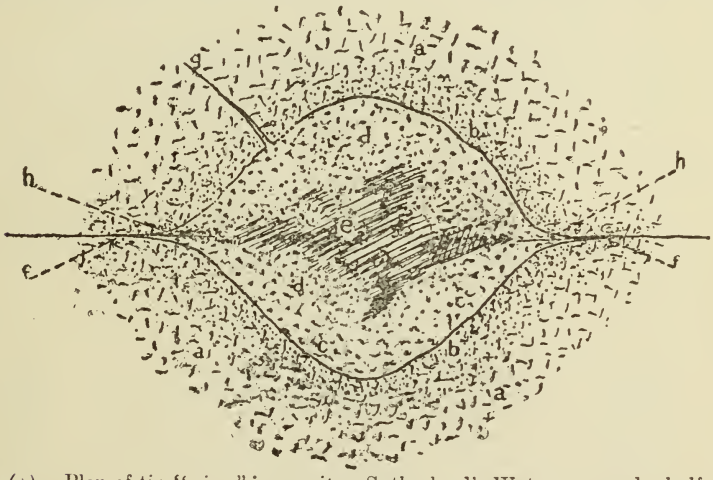

Fig. 8 (A).—Plan of tin "pipe" in granites, Sutherland's Water, one and a half miles west of Tingha.

a Unaltered hornblendic granite.
b Granite and ferromagnesian constituents changing to chlorite and sericite.
c More advanced phase of alteration. White felspar and sericite developing.
d White felspar, drusy by partial removal of sericite. Small tin percentages.
e Change to solid tinstone.
f and *g* Intersecting joints, determining "pipe."
h Great alteration of country to felspar and sericite along joint.

Graney's Lode, near Emmaville, is also an example of a pipe vein in hard granite country. It is oval in cross-section, and contained abundant felspar in the gangue. Professor David described it as "a carbona or impregnation of the flattened sausage type."

The dip varied considerably, as is shown by the following readings :—

From 0–20 feet dip, 20° north of east at 55°.
From 20–50 feet dip, 5° north of east at 45°.
From 50–60 feet vertical.

Stockworks.—Minute veins of tinstone occur in quartz-porphyry or felsite in many places, forming what are known as "stockworks." The minute veins appear to follow joints, which cross one another in many directions in the intrusive rock.

* Records Geol., Survey N. S. Wales, 1907, viii, p. 240.

The following are examples of this type of occurrence:—

(*a*) *Bath's Lode*, near Emmaville—
Here the quartz and tinstone are arranged on either side of a central crack and merge gradually into quartz-porphyry.

(*b*) *Browne's Lode*, Bark Hut Creek—
This lode cuts across a belt of aplite at an acute angle. In the latter numerous thin veins occur as joint fillings from $\frac{1}{16}$ to $\frac{1}{4}$ in. thick, and the tinstone is associated in places with quartz; in other places it is seen crystallized alone on the joint faces. Molybdenite is associated with the tinstone in small quantities.

(*c*) *Butchart's Lode*, 2 miles north of Tingha—
A "stockwork" is formed by a number of cross veins in a belt of aplite 50 ft. to 60 ft. wide, impregnated with tinstone.

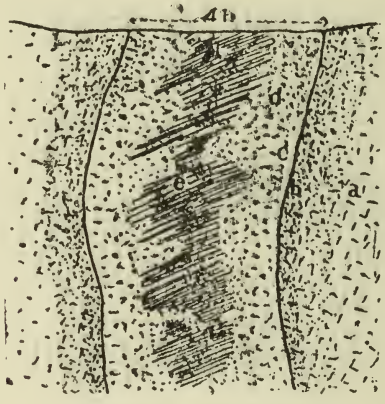

Fig. 8 (B)—Section of "pipe."

It will be understood from the geographical positions of the different deposits already alluded to that tin is very widely distributed in New South Wales. It is in the northern portion of the colony that the principal deposits occur. From a point north of Tamworth, tin-bearing rocks extend northwards with breaks to the Queensland border. The mean width of this area is about 30 miles and within it are the Bendemeer, Inverell, Tingha, and Emmaville districts, the latter including the Nine-mile, Torrington, and the Mole Tableland; the district to the east and south-east of Glen Innes and Deepwater, including Oban, Pheasant's Creek, Back Creek, and Ding Dong; and still further north, the Wilson's Downfall district, which may be regarded as an extension eastwards of the Stanthorpe tin-bearing area of Queensland.

Tin dredging.

Under the general title of "dredging" by common usage are included both bucket and suction plants, whether the latter be stationary or on a movable barge or pontoon.

Suction-pump methods are more correctly hydraulic sluicing where forced steam pressure takes the place of natural gravity force.

The suitability and efficiency of the bucket or suction plant is determined by the nature of the ground to be operated on. Rough, uneven, bottoms, with joints, cleavages, or other crevices serving as natural riffles for the metallic or heavy ore particles, are best attacked by the powerful nozzles or "Monitors" of the suction method. Soft, rotten, bottoms on the other hand, may, perhaps, be more economically worked by the bucket type.*

Tin dredging has been, and is being, extensively carried on by the methods above referred to, along the course of many New England streams, and on surface deposits of that district with profitable result, and has been particularly successful on those stretches of alluvial drift where thickness of stripping and presence of heavy water precluded satisfactory recovery of the tin contents by the old method of box-sluicing.

Operations began in 1900, when the Cope's Creek Proprietary Company leased a large area of land along Cope's Creek in the vicinity of Tingha. Since that time many dredging plants have been established in the Tingha, Emmaville, Wilson's Downfall, Deepwater districts, as well as at Bendemeer, Severn River, Glen Elgin, Guyra, Backwater, and Mitchell River. Last year (1919), there were sixty-two dredges in operation, and the estimated value of the plants was £269,000.

The yield obtained by the tin dredges during the past twenty years is shown by the following statement :—

Year.	Stream Tin.	
	Quantity.	Value.
	tons.	£
1900	.....	.....
1901	49	3,542
1902	110	8,300
1903	244	20,100
1904	319	26,180
1905	532	50,904
1906	1,032	120,661
1907	1,692	176,212
1908	1,562	129,952
1909	1,677	146,842
1910	1,607	158,467
1911	1,742	208,095
1912	1,621	223,813
1913	1,819	239,958
1914	1,205	119,167
1915	1,164	116,549
1916	1,272	146,880
1917	1,207	183,156
1918	1,253	282,338
1919	1,083	174,013
1920	1,063	176,834
1921	768	76,550
Total	23,021	2,788,563

Production.—New South Wales contributes a little more than one-third of Australia's total production of tin, which, in turn, is roughly 3½ per cent. of the world's total.

* J. E. Carne, Min. Resources No. 14, p. 300.

The following table shows the estimated production of tin since the opening of the tin-fields in 1872 to the end of 1919 :—

Year.	Ingots.					Ore.					Total Value.		
	Quantity.		Value.			Quantity.		Value.					
	tons.	cwt.	£	s.	d.	tons.	cwt.	£	s.	d.	£	s.	d.
1872											12,227	0	0
1873											249,887	0	0
1874	5,443	11	523,880	0		8,649	5	472,286	0	0	372,777	0	0
1875											361,275	0	0
1876	3,465	0	239,100	0	0	1,509	5	60,340	0	0	299,440	0	0
1877	3,279	8	218,348	0	0	823	15	30,558	0	0	248,906	0	0
1878	2,894	15	179,528	0	0	1,169	0	35,085	0	0	214,613	0	0
1879	3,281	5	225,908	0	0	844	6	30,374	0	0	256,282	0	0
1880	3,910	19	323,425	0	0	684	12	30,827	0	0	354,252	0	0
1881	5,824	1	531,303	0	0	609	6	37,492	0	0	568,795	0	0
1882	5,101	2	508,523	0	0	610	19	32,890	0	0	541,413	0	0
1883	4,643	12	427,202	0	0	445	4	21,685	0	0	448,887	0	0
1884	3,362	0	266,325	0	0	349	13	14,861	0	0	281,186	0	0
1885	3,338	8	283,592	0	0	534	18	25,168	0	0	308,760	0	0
1886	2,664	18	259,195	0	0	326	18	18,350	0	0	277,545	0	0
1887	2,625	6	295,478	0	0	291	13	16,411	0	0	311,889	0	0
1888	2,260	13	296,196	0	0	247	8	13,314	0	0	309,510	0	0
1889	2,084	10	195,865	0	0	234	7	11,805	0	0	207,670	0	0
1890	1,725	18	166,333	0	0	259	4	12,724	0	0	179,057	0	0
1891	1,454	2	124,320	0	0	203	5	9,643	0	0	133,963	0	0
1892	1,485	2	140,421	0	0	239	2	12,573	0	0	152,994	0	0
1893	1,393	2	119,510	0	0	148	1	6,604	0	0	126,114	0	0
1894	1,137	17	77,512	0	0	190	7	7,752	0	0	85,264	0	0
1895	1,325	3	85,394	0	0	77	4	2,543	0	0	87,937	0	0
1896	1,128	18	65,641	0	0	96	19	2,905	0	0	68,546	0	0
1897	786	9	49,340	0	0	14	2	560	0	0	49,900	0	0
1898	628	15	45,603	0	0	1	4	35	0	0	45,638	0	0
1899	739	4	90,037	0	0	7	6	445	0	0	90,482	0	0
1900	1,070	9	141,824	0	0	15	2	900	0	0	142,724	0	0
1901	648	10	76,080	0	0	10	17	464	0	0	76,544	0	0
1902	493	15	58,521	0	0	22	19	1,072	0	0	59,593	0	0
1903	933	10	120,778	0	0	546	14	29,430	0	0	150,208	0	0
1904	1,073	14	138,881	0	0	626	4	49,496	0	0	188,377	0	0
1905	1,170	2	163,595	0	0	786	9	62,515	0	0	226,110	0	0
1906	1,161	0	205,373	0	0	510	0	50,371	0	0	255,744	0	0
1907	1,331	0	229,607	0	0	583	0	63,698	0	0	293,305	0	0
1908	954	0	126,292	0	0	841	0	79,155	0	0	205,447	0	0
1909	951	0	127,089	0	0	992	0	83,940	0	0	211,029	0	0
1910	847	0	127,700	0	0	1,021	0	100,456	0	0	228,156	0	0
1911	958	0	191,000	0	0	971	0	116,089	0	0	307,089	0	0
1912	900	0	183,000	0	0	1,175	6	155,074	0	0	338,074	0	0
1913	903	0	182,800	0	0	2,117	12	238,492	0	0	421,292	0	0
1914	650	0	101,400	0	0	1,667	0	165,730	0	0	267,130	0	0
1915	857	0	135,350	0	0	1,331	0	131,430	0	0	266,780	0	0
1916	909	0	159,075	0	0	1,220	0	147,422	0	0	306,497	0	0
1917	1,109	0	240,410	0	0	963	0	133,286	0	0	373,696	0	0
1918	1,182	0	388,900	0	0	738	0	159,976	0	0	548,876	0	0
1919	1,146	0	265,260	0	0	1,546	4	151,363	0	0	416,623	0	0
1920	887	0	257,514	0	0	2,486	0	413,794	0	0	413,794	0	0
1921	816	0	133,521	0	0	1,595	0	163,451	0	0	163,451	0	0
Totals	86,935	0	9,491,949	0	0	40,332	0	3,404,834	0	0	12,505,748	0	0

The following is a list of localities where tin is known to occur in New South Wales. It should be noted, however, that, in many instances, the ore has been recorded as speciments only :—Adaminaby, Albury, Ardlethan, Attunga, Badjerrigarn, Ballina, Barmedman, Barraba, Basin Creek, Beach Sands, Beechwood, Bega, Bendemeer, Bingara, Bolivia, Bombala, Boonoo Boonoo, Boorolong, Boro, Brassington, Bundarra, Bungendore, Bungonia, Bygoo, Cangai, Carrai, Carroll's Creek, Cathcart, Commissioners' Creek, Condobolin, Copeton, Coppabella, Corona, Dalgety, Deepwater, Delegate, Delungra, Dubbo, Dulah, Eremeran, Euabalong, Euriowie, Felton's Creek, Fifield, Gibraltar, Glendon, Glen Elgin, Glen Innes, Gobondery, Grafton, Grenfell, Grey Mare's Tail, Grong Grong, Gulgong, Gundle, Guy Fawkes, Guyra, Hamilton River, Hastings River, Hillgrove, Holbrook, Howell, Inverell, Jacob's Swamp, Jerrawangala, Jindabyne, Jingellic, Kempsey, Kingsgate, Kolkilberton, Kookarabooka, Kosciusko, Lake Mount, Lowry Creek, Macleay River, Mandamah, Manildra, Mount Tallebong, Marulan, Murrurundi, Nimmitabel, Pheasant Creek, Pilot Mountain, Pulletop Creek, Purnamoota, Quart Pot Creek, Quirindi, Rankin's Springs, Sandy Mount, Sheep Station Creek, Shellharbour, Sidmouth Valley, Stuart Town, Sunny Corner, Temora, Tenterfield, Termeil, Tingha, Torrington, Tumbarumba, Tumut, Ungarie, Uralla, Vegetable Creek, Wagga Wagga, Walcha, Warialda, Wellingrove, Werong Mount, Wilson's Downfall, Woodburn, Wyalong, Yalgogrin, Yambulla, Yancowinna Creek.

For detailed references to reports of the Department, see Mineral Resources No. 28.

For further detailed information respecting the tin deposits of New South Wales, the following works should be consulted :—

Mineral Resources Series.

No. 14.—"The Tin Mining Industry and the Distribution of Tin Ores in New South Wales"; by J. E. Carne, F.G.S.

No. 20.—"Report upon the Ardlethan Tin-field"; by J. R. Godfrey, B.A.

No. 29.—"The Geology and Mining Developments of the Ardlethan Tin-field"; by L. F. Harper, F.G.S.

Geological Memoirs.

No. 1.—Report on the Vegetable Creek Tin Mining District; by T. W. E. David, B.A., F.G.S.

Sydney: William Applegate Gullick, Government Printer—1922.